Overview Summary/ Abstract

The ISS currently uses Ni-H2 batteries in the main power system. Although Ni-H2 is a robust and reliable system, recent advances in battery technology have paved the way for future replacement batteries to be constructed using Li-Ion technology. This technology will provide lower launch weight as well as increase ISS electric power system (EPS) efficiency. The result of incorporating this technology in future re-supply hardware will be greater power availability and reduced program cost. The presentation will outline some of the major benefits and safety considerations of incorporating the new technology.

Li-Ion Battery for ISS

Space Power Workshop
April 2004

Fred Cohen
The Boeing Company

Penni Dalton
NASA Glenn Research Center

Overview Summary/ Abstract

The ISS currently uses Ni-H2 batteries in the main power system. Although Ni-H2 is a robust and reliable system, recent advances in battery technology have paved the way for future replacement batteries to be constructed using Li-Ion technology. This technology will provide lower launch weight as well as increase ISS electric power system (EPS) efficiency. The result of incorporating this technology in future re-supply hardware will be greater power availability and reduced program cost. The presentation will outline some of the major benefits and safety considerations of incorporating the new technology.

Why Use Li-Ion Batteries for ISS

- Significant Program Cost Savings
  - Reduced cost of battery re-supply procurement
  - Reduced weight and volume will provide significant launch cost benefits to NASA

- Technical benefits of Li-Ion Battery Technology are Real
  - Increased EPS performance
  - Decreased launch weight or increased life
  - Higher operational thermal limits

- New battery subsystem integration can be performed with minimal vehicle impact

- Operation with any Ni-H2 / Li-Ion Battery combination on Integrated Equipment Assembly (IEA) allows greater logistics flexibility

Why Li-Ion Battery For ISS?

Overall Design Performance Parameter Battery Level Comparison

Parameter	Li-Ion	Ni-H2	Comment
Cell energy density @ 100% DOD, W.hr/l	250	50	One Li-Ion ORU can replace multiple Ni-H2 ORUs
Battery specific energy @ 100% DOD, W.hr/kg	~80	29	Lower equivalent launch weight
Nameplate capacity, kW-hr / Battery	>10	8.4	Will result in higher reserve capacity for contingencies
Operating voltage range, V	81 to 123	76 to 125	Voltage range is compatible with in situ hardware
Normal operating DOD, %	15 to 25	34	
Roundtrip efficiency @ BOL, %	≥95	85	
Roundtrip efficiency @ EOL, %	>85	80	
Operating temperature range, deg. C	0 to 40*	0 to 10	
Non-operating temperature range, deg. C	-40 to +40	-10 to +20	
Design life, years	6.5	6.5	Reduced logistics and launch costs (fewer launches)

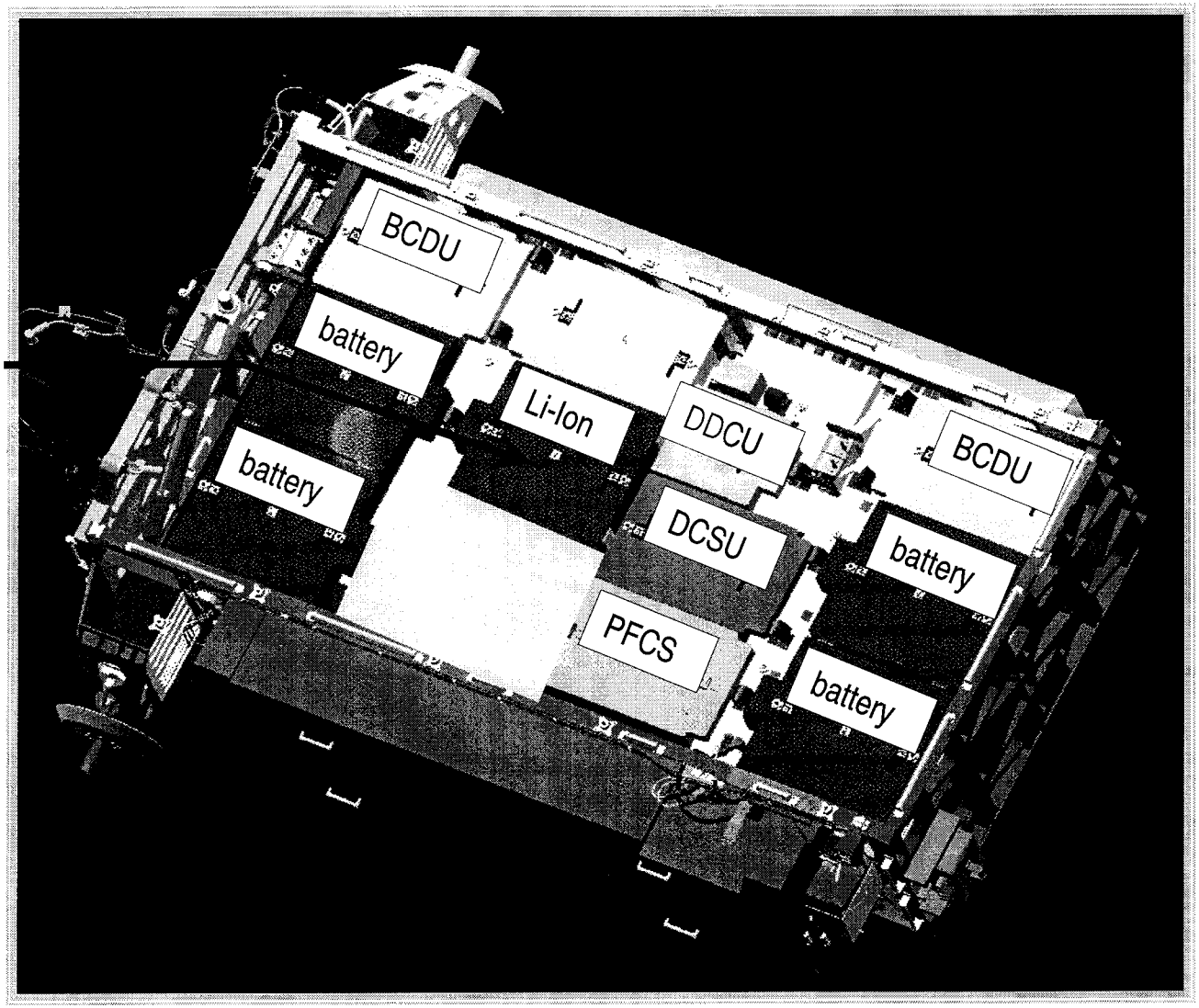
* Manufacturer/chemistry dependent

- **Higher nameplate capacity will result in more power reserve for contingencies**
- **Higher roundtrip efficiency will result in greater continuous power to the users**
- **Initially: Two Ni-H_2 battery Orbital Replacement Units (ORU) can be replaced with a single Li-Ion battery ORU, resulting in a weight saving of ~45% per battery.**
- **Considerable ISS life cycle cost savings due to fewer Battery ORUs**
- **Reduced on-orbit start-up time resulting from launch of charged Li-ion versus discharged Ni-H_2 batteries (present plan)**

Li-Ion Battery Replacement Concept

Spare Li-Ion Battery ORU launch on FSE for On-Orbit Use

Only one ORU necessary for Li-Ion



System Objectives / Targets

- **Li-Ion battery shall be designed to meet or exceed existing battery performance/life requirements.**

- **Any power channel will be able to support a combination of batteries - one or more Ni-H2 battery(s) and one or more Li-Ion battery(s) on the same power channel.**

- **Goal is for replacement hardware to be "plug and play" to minimize impacts to the present ISS hardware and software.**

Current Battery Design Requirements

- Nameplate Capacity ≥ 81 A.hr
- Satisfy following power requirements:
  - Peak power at 6000 W for 5 minutes during eclipse or insolation period
  - Continuous power at 4600 W
  - Contingency discharge power at 1300 W for 92 minutes following a normal orbit
  - Offloaded configuration, continuous power at 7220 W
- Voltage range, during charge and discharge, not to exceed 76 to 125 V
- Capable of full charge in 4 orbits or less
- Roundtrip energy efficiency ≥ 80%
- Provide fault protection to the main power cables
- Each battery ORU shall weigh <375 lb (two ORUs make a battery)
- Design life of the battery 6.5 years with a storage life of 4 years
- Safety:
  - No fault propagation
  - Single fault tolerant to critical hazards
  - Two fault tolerant to catastrophic hazards
- Withstand specified thermal environments and MMOD exposure
- Withstand launch loads

Li-ion battery expected to meet or exceed these requirements

Li-Ion Battery ORU Description

- Li-Ion will replace Ni-H_2 battery technology.

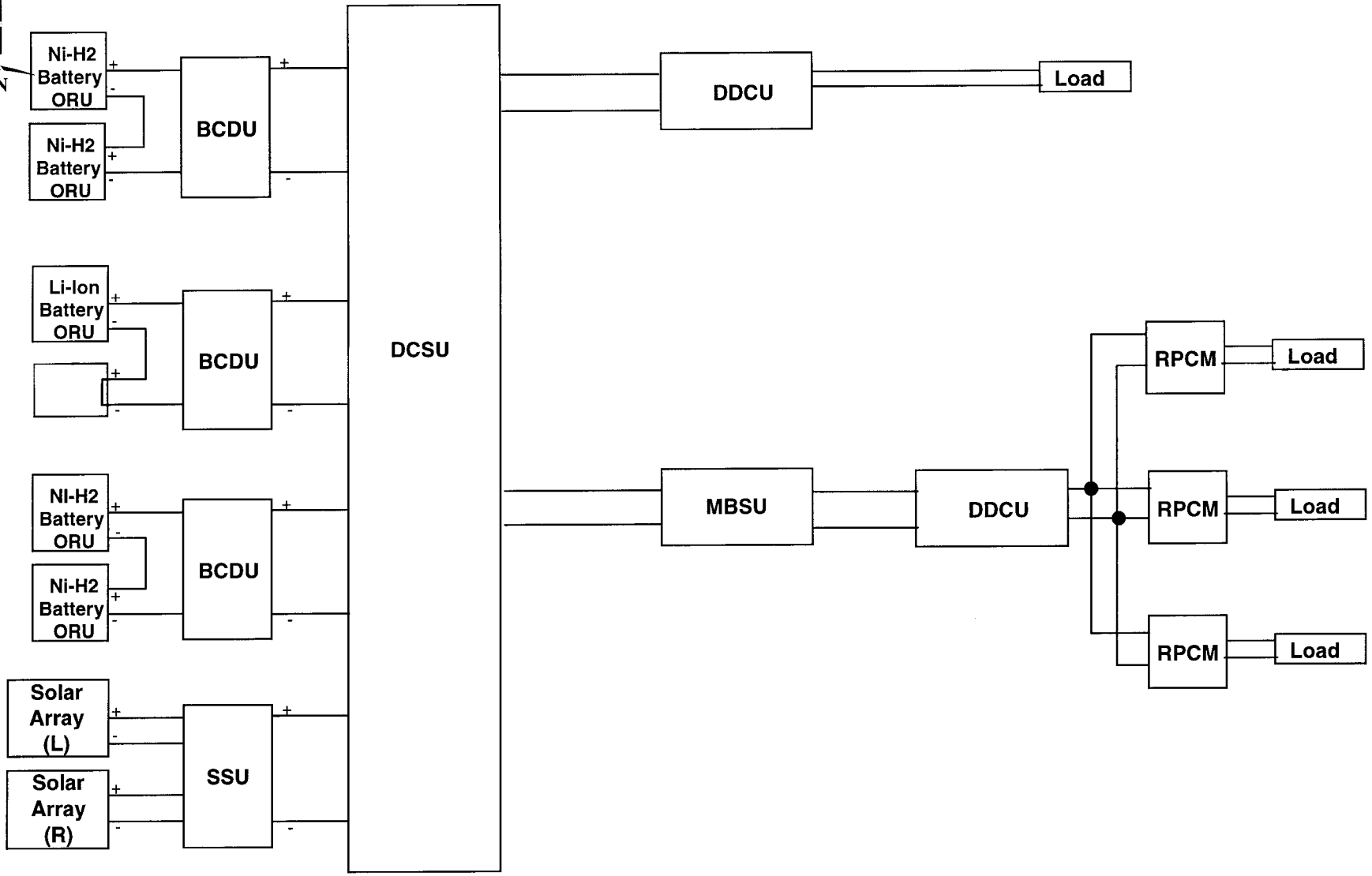
  - ORU box design will be similar to the current Ni-H2 ORU box
    - Identical baseplate fins to interface with finned coldplate
    - Identical box and cover with its thermal protection
    - Identical power, data and control connectors

  - An interface unit will be provided for connection to the BCDU. It will, in conjunction with BCDU perform charge control, heater, and dead-face (for safe ORU handling) functions.

  - Heaters will be provided for low load operations and to thermally balance all battery ORUs within a power channel

Simplified ISS EPS Block Diagram

(One Channel)



Charge/Thermal Control

- **Charge control**
  - Would be (primarily) based on voltage data from cells.
  - Several charge control algorithms may be incorporated.
  - Multiple safety monitoring and mitigation methods will be employed
- **Existing TCS has more than adequate capacity for new battery system**
- **Heater control**
  - Will have series redundant switching.
  - Thermal control system will utilize multiple sensors

System Summary & Conclusions

- Change to Li-Ion would be transparent to ISS except for changes to the Portable Computer System (PCS) and Mission Control Center (MCC) displays

- Higher efficiency and higher capacity of Li-Ion batteries will enhance power channel power capabilities - continuous power and contingency power

- Safety aspects of the Li-Ion batteries are understood and the proposed design will incorporate fault protection circuitry.

- Change from Ni-H2 to Li-Ion battery can save launch weight and cost